STATE OF ILLINOIS

STATE HIGHWAY DEPARTMENT

BULLETIN NO. 6

ON

Dust Prevention

Including Specifications for Oils and Tars Used in the Surface Treatment of Various Types of Roads.

Prepared By

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Testing Engineer, Illinois Highway Department.

Springfield, Illinois, March, 1915.

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BY

F. L. ROMAN, Testing Engineer.
Illinois Highway Department.

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PREFACE.

The State Highway Department has in the past year received numerous requests for information pertaining to dust prevention in general, and to surface oiling of macadam, gravel and dirt roads in particular. The following treatise has been prepared in an attempt to compile in readily available form, data and suggestions which would answer these inquiries in many instances, and which would educate the public to the various ways of eliminating dust. It is not intended to cover in detail all that might be said in regard to dust prevention, but rather to give a general outline of the subject, together with suggestions as to practical methods to eliminate dust. An effort has been made to write this bulletin, as far as possible, in plain, non-technical language and to deal with the subject in such a way as to be helpful to township, county and city officials who are required to cope with the dust problem.

INTRODUCTION.

The formation of dust on roads and its prevention by various means has given rise to serious problems. While the dust nuisance has been a source of annoyance for a number of years, little attention has been given to the means of preventing dust until recent years. With rapid increase in population and traffic, and the advent of motor-driven vehicles, the formation of road dust in excessive quantity has become a public menace as well as a public nuisance. Dust carries filth and disease germs, and is an important cause of disease to mankind and animals; it is unsightly on trees, shrubbery and plants, and when deposited in large quantities, is disastrous to vegetation; it is not only a source of annoyance to traffic by soiling clothes and vehicles, but is a danger when forming clouds which obstruct the traveled way and conceal the presence of fast moving vehicles; it is a perpetual nuisance to residents along highways, by damaging clothing and household furnishings and causing much personal discomfort.

DUST FORMATION.

The fundamental cause of dust formation on roads is wear. Other factors, such as the transportation and deposition on the

Figure 1. The Scraping on the Highways of the Sod and Debris from the Ditches is Often the Cause of the Bad Condition of the Road.

road of foreign material, should also be taken into consideration, but the dust due to the last cause is, however, generally of small importance compared to that due to wear.

Broadly speaking, wear on a road surface consists of the breaking up of the solid road surface into fine particles, or dust. This action takes place under the various forces due to traffic mainly, such as the grinding of the steel tired wheels, the blows of horses' hoofs, the local compression of narrow tires from vehicles heavily loaded, the frictional effect of motor-driven vehicles, etc. Some action is due also to frost, rain, wind and other weathering agencies which tend to disintegrate the road surface.

Foreign materials carried on the road by traffic may be deposited already as dust or may be converted into dust by the same wearing agencies which have been described above. The dust from this source is of special importance, mainly in thickly settled districts where the dust on roads is sometimes due almost entirely to foreign matter.

Wind and traffic raise the dust formed from wear or other agencies, and the discomforts resulting are too well known to

Figure 2. The Highways Are Often Considered as Dumping Grounds for All Sorts of Refuse. The Placing of Rubbish on Highways or in the Side Ditches Should Not Be Permitted.

require further discussion. This dust nuisance has been greatly increased, however, by the use of fast moving motor vehicles. The partial vacuum and suction which are produced behind the body of an automobile draw the dust into the air and the air currents resulting from the passage of high speed vehicles scatter the dust over the surrounding country. The higher the speed of the machine, the larger will be the amount of dust raised.

The effect of automobiles on certain types of roads is well known. On stone and gravel roads, the friction of the wheels of motor driven vehicles, and the suction of these vehicles when driven at high speed, remove the fine particles which are necessary to bind the stones, and the road is torn up in a short time. These conditions of stone and gravel roads are not general, however, in this State, as there are many sections in Illinois where motor

traffic is yet very light, but they have been discussed to show the necessity of providing for new conditions of traffic.

It should be noted in regard to automobile traffic, that while motor vehicles have undoubtedly caused much trouble on certain types of road, that many types of pavements withstand automobiles much better than horse-drawn vehicles. If the dust problem alone is considered, it should be remembered also that the dust nuisance existed on a somewhat smaller scale long before the first automobile was constructed, and that if self-propelled vehicles have temporarily increased the dust nuisance, they have also aroused the public at large to the knowledge that good roads are necessary to the welfare of any community. Bad roads are as injurious to the automobile as self-propelled vehicles are to some types of road, and consequently the automobile has been instrumental in the construction of many miles of good roads. A large portion of the money spent on the roads of Illinois during the past two years has been

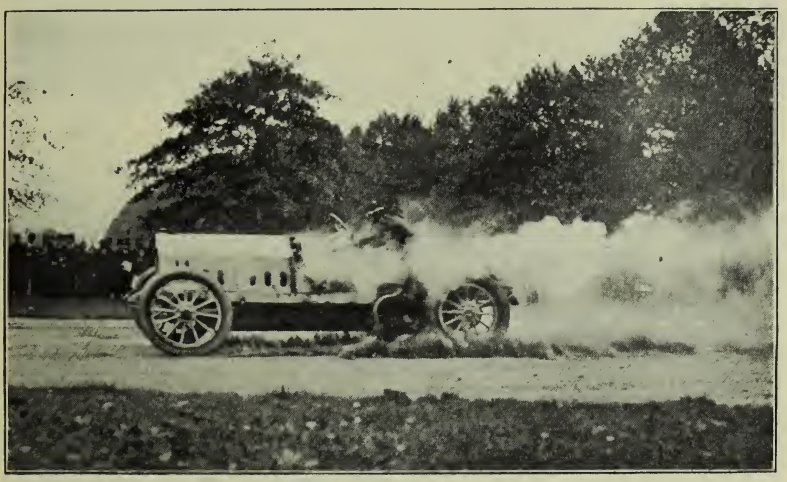

Figure 3. Dust Raised by Automobile Going 80 Miles an Hour.

furnished by automobile taxation, and automobile clubs have in various ways cooperated in building good roads. The coming of the automobile has done much towards revolutionizing our transportation facilities and increasing the religious, educational and industrial welfare of the community, and the above discussion on automobile traffic has been written in an effort to dispel the feeling still retained by a few, that automobiles are a nuisance on highways and that modern road legislation is of benefit only to automobilists.

DUST PREVENTION.

Many methods to eliminate the dust nuisance on roads have been tried, but the dust problem may be solved only in three general ways: first, by the sanitary removal of the dust; second, by the

construction of roads which will not form dust; and third, by the retention of the dust formed on the road surface.

The first of these methods applies mainly to city pavements

Figure 4. An Old Macadam Road in Bad Condition.

and requires either sweeping the streets or washing them with water under pressure. It is impracticable on country highways and will not be given further consideration in this publication.

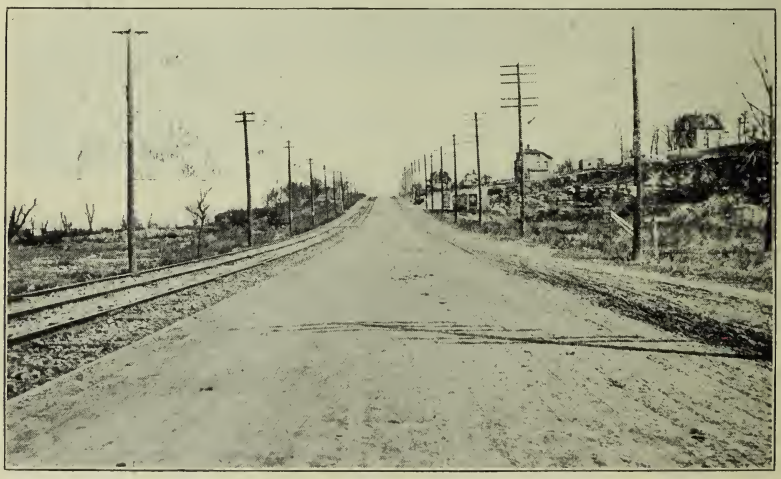

Figure 5. The Same Road as Shown in Figure 4 After Improvement.

The methods of dust prevention, involving either the construction of roads which will not form dust, or the retention of the dust formed on the road surface are closely related and will be discussed together, in connection with the various types of roads.

DUST ON PAVEMENTS.

Pavements are generally understood to mean brick, concrete, creosoted block, asphalt, tar and similar types of roads. They are the most resistant to wear and form very little dust when properly constructed. The dust accumulating on these roads is due almost entirely to foreign matter carried on the road by traffic. A discussion of the methods of construction of pavements is beyond the scope of this bulletin and will not be undertaken.*

Road preservation and dust prevention are, however, so closely associated in certain types of roads that it will be necessary to consider the repairing of some types of pavements in connection with dust prevention.

DUST PREVENTION ON CONCRETE AND BRICK ROADS.

As stated before, concrete and brick roads form very little dust. In cities, however, a large amount of dust from foreign materials often accumulates on these pavements and it is necessary to resort

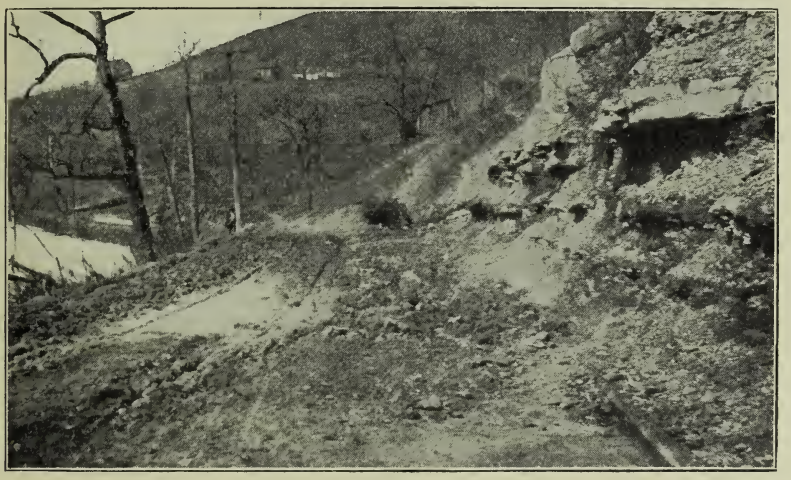

Figure 6. Showing End of Brick Pavement and the Bad Conditions of an Earth Road from Which Mud Is Carried onto Pavement by Traffic.

to sweeping or washing at frequent intervals. As this causes a heavy expense, solutions of calcium chloride and other dust palliatives have been applied with some success to these pavements to retain the dust on the road surface. Their effect in cities, is at best only temporary, but as the dust does not have to be removed so frequently, the saving effected may more than offset the extra cost of these treatments. Applications of calcium chloride and

* For methods of construction see the specifications of the Illinois Highway Department for various types of pavements. Copies of the following specifications may be obtained free of charge: Brick Road Construction; Concrete Road Construction; Waterbound Macadam Construction; Bituminous Macadam Construction, comprising asphalt or tar road construction.

similar products are especially effective in the suburbs of large cities where the removal of dust is very difficult and expensive. Brick and concrete roads on rural highways show, in general, very little dust, and the rains are usually sufficient to wash off the dust and impurities deposited by traffic.

ASPHALTS AND TARS ON CONCRETE AND BRICK ROADS.

The application of asphalts and tars on concrete and brick roads has been tried repeatedly in many cities. These experiments have been, in general, a waste of time and money, and have been at best only temporarily successful. While it is undoubtedly true that the application of a bituminous surface on concrete or brick will render these pavements practically noiseless and will tend to retain the dust to some extent, it has been found difficult to build a mat of this type which will not peel or "pick up" in patches. The accumulation of foreign matter on the road has furthermore a destructive influence on the thin bituminous mats used, and bituminous surfaces less than ½ inch in thickness soon wear out.

DUST ON CREOSOTED BLOCK PAVEMENTS.

Creosoted block pavements form practically no dust and when new tend to lay the dust which is brought on their surface by traffic. These blocks are treated with creosote oils under pressure, and contain generally from 10 to 20 pounds of the oil per cubic foot of lumber. During warm weather, when the dust nuisance is greatest, a small amount of oil is generally forced out of the blocks through expansion. This oil will have the tendency to lay the dust, and if the foreign material deposited on the pavement is removed before it has accumulated to a great thickness, the road will remain practically dustless. These creosoted block pavements lose somewhat their property of laying dust when old, but when the dust question alone is considered, they compare favorably with concrete and brick pavements and often with bituminous surfaces. Up to the present time creosoted blocks have not been used on rural roads in this State, but have been used mainly in cities, and to some extent in the suburbs of large cities.

DUST ON BITUMINOUS PAVEMENTS.

The bituminous pavements include asphalt, tar and similar types of roads, but in the following discussion they are not understood to mean various types of pavements to which a light mat or carpet of bituminous material has been applied. A large number of bituminous pavements have been built within the last five years, and the popularity of this type of pavement is due to a large extent to the fact that it remains practically dustless under ordinary conditions. In cities, where a large amount of foreign material is deposited on these pavements, they should be cleaned at frequent intervals, not only to assist them in keeping a dustless sur-

face, but because the dust and especially the dung of animals is injurious to this type of construction. On rural highways the amount of dust carried on the road is usually comparatively small and the rains are sufficient to wash the bituminous surface free of foreign deposits. Where short sections of bituminous roads have been built, large quantities of mud are often carried on these pavements from the adjacent earth roads and should be removed. The

Figure 7. A Bituminous Macadam Road Four Years Old in Very Good Condition. The Leaves and Debris Should Be Removed from the Gutters.

use of a light road grader or drag to clean the surface by scraping off the mud has been suggested, but is not always practicable. The building of a few yards of stone or gravel roads at each end and on the cross roads would usually prevent, to some extent, this occurence.

THE REPAIRING AND SURFACING OF BITUMINOUS ROADS.

The mat surface of bituminous roads wears off slowly and after a certain length of time, depending on the amount of traffic carried by the road and various other conditions, will be worn through, and the stone will be required to sustain the main part of the wear due to traffic. With the soft limestones commonly used in Illinois, the road will no longer remain dustless and will deteriorate rapidly. The careful inspection of many bituminous macadam roads of this State has always shown that a mat surface into which has been incorporated a hard silicious material will wear much better than the body of the road, and that it is therefore, advisable to apply occasionally a new carpet of bituminous material to take the wear.

The bituminous material used for this surface treatment should be applied only after the road has been swept clean and after all irregularities of the surface have been eliminated by proper repairs. All depressions should be filled with bituminous material and

gravel or stone chips, so that the entire road surface is hard and even. The application of the bituminous material may be made either by hand or by mechanical methods. In the hand method, ordinary pouring cans are used and filled from a large supply tank that is driven along beside the work. It is very difficult to apply the bituminous material evenly with a pouring can, and it is necessary to immediately follow the application with a brush broom and sweep the surplus oil ahead. This method of applying the material is very slow and expensive and is seldom used today, except for small jobs and patch work.

There are a great many different types of mechanical distributors on the market, and a number will apply equally well light or heavy bituminous materials. The apparatus which is used by the Illinois Highway Department is described in connection with the construction of bituminous surfaces on waterbound macadam

Figure 8. A Bituminous Macadam Road in a Very Bad Condition. The Road Should Be Patched and Resurfaced. The Condition of the Road Appears to Be Due Partly to Improper Construction and Partly to Lack of Maintenance.

roads. The bituminous material is applied at the rate of about ½ gallon per square yard and should be covered with only the quantity of clean coarse sand which will be required to prevent it from adhering to wheels. When hot bituminous materials are used, the application of sand should follow at once. On heavily traveled roads, much better results can be secured by applying the bituminous surface in two courses. The first treatment should consist of about ¼ gallon of material per square yard and should be covered with torpedo gravel of ⅜ to ⅛ inch size, or, if gravel is not available, with clean stone chips. After rolling, a second treatment of about ¼ gallon of bituminous material per square yard is applied. Clean coarse sand is spread over the surface and the road rolled a second time. The entire treatment will require from ½ to ¾ gallon of bituminous material per square yard, and one cubic yard of coarse sand or chips for about every 125 square yards of surface treated.

The resulting mat should be about ⅜ inch thick, and the more uniform the thickness is the better will be the results obtained. A one course treatment with the lighter oils given under specifications No. 2, should require from ⅓ to ½ gallon of oil and one cubic yard of sand, for every 150 square yards of surface.

Asphalts and tars may be used for bituminous roads and for surface treatments with about equal success. A good asphaltic oil would be preferred to a tar of poor quality, but a tar of good quality would be preferred to a greasy paraffin asphalt. It is not advisable, however, to use a tar product on an asphalt road, nor an asphalt on a tar road, and a bituminous road should be repaired and re-surfaced with a material of the same nature as that used in its construction. The following specifications are given as a guide for the selection of the best grades of asphaltic oils and

Figure 9. Road Showing Surface Bituminous Mat Worn off in Spots and Requiring a Surface Application of a Good Bituminous Material.

coal tar products suitable for the surface treatment of bituminous roads. The price of the bituminous products meeting the requirements of the following specifications varies from about 6 cents to 16 cents per gallon, and the cost per square yard of this surface construction will vary from about 6 cents to 20 cents, depending upon the quality and quantity of the oil used and local conditions. Specifications No. 1 are to be used for heavy asphaltic oils which are very viscous and sticky at ordinary temperatures, and which must be heated before application. Specifications No. 2 are intended for asphaltic or semi-asphaltic oils of medium weight which can be applied cold, when the air temperature is at least 80 degrees F. Specifications No. 3 are to be used for refined coal tar products which are viscous at ordinary temperature and should be applied hot. Lighter bituminous materials are not recommended for this type of construction, but if desired, may be obtained by requiring products meeting specifications Nos. 4 or 5.

SPECIFICATIONS NO. 1.

HEAVY OIL FOR SURFACE TREATMENT OF BITUMINOUS OR WATERBOUND MACADAM.

(Hot Application.)

1. The oil shall be a very viscous fluid product, free from water.

2. *Specific Gravity.* Its specific gravity at 25° C. (77° F.) shall not be less than 0.980.

3. *Total Bitumen.* It shall be soluble in chemically pure cold carbon disulphide to the extent of at least 99.5 per cent.

4. *Naphtha Insoluble Bitumen.* Of the total bitumen not less than 10 nor more than 25 per cent shall be insoluble in 86° B. paraffin naphtha, at air temperature.

5. *Fixed Carbon.* The fixed carbon shall not be less than 5.0 nor more than 13.0 per cent.

6. *Penetration.* The penetration of the material as determined with a Dow machine, using a No. 2 needle, 100 grams weight, 5 seconds time and a temperature of 25° C. (77° F.) shall not be less than 25 mm.

7. *Viscosity.* When 240 cc. of the oil are heated in an Engler Viscosimeter to 100° C. (212° F.) and maintained at this temperature for 3 minutes, the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than five (5.0). In this test special care should be taken to prevent any appreciable loss through volatilization.

8. *Loss on Evaporation.* When 20 grams of the oil (in a tin dish, 2½ inches in diameter and ¾ inch deep with vertical sides) are maintained at a temperature of 163° C. (325° F.) for 5 hours in a N. Y. Testing Laboratory oven, the loss shall not exceed 15 per cent by weight.

9. *Flash Point.* The flash point of the oil by the open cup method should not be less than 100° C. (212° F.)

SPECIFICATIONS NO. 2.

MEDIUM OIL FOR SURFACE TREATMENT OF BITUMINOUS OR WATERBOUND MACADAM.

(Should Be Applied Hot When Air Temperature Is Below 80° F.)

1. The oil shall be a viscous fluid product, free from water.

2. *Specific Gravity.* Its specific gravity at 25° C. (77° F.) shall not be less than 0.950.

3. *Total Bitumen.* It shall be soluble in chemically pure cold carbon disulphide to the extent of at least 99.5 per cent.

4. *Naphtha Insoluble Bitumen.* Of the total bitumen, not less than 5 nor more than 20 per cent shall be insoluble in 86° B. paraffin naphtha at air temperature.

5. *Fixed Carbon.* The fixed carbon shall not be less than 4.0 nor more than 12.0 per cent.

6. *Viscosity.* When 240 cc. of the oil are heated in an Engler Viscosimeter to 50° C. (122° F.) and maintained at this temperature for 5 minutes, the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than thirty (30) nor more than seventy (70).

7. *Loss on Evaporation.* When 20 grams of the oil (in a tin dish 2½ inches in diameter and ¾ inch deep with vertical sides) are maintained at a temperature of 163° C. (325° F.) for 5 hours in a N. Y. Testing Laboratory oven, the loss shall not exceed 25 per cent by weight.

8. *Flash Point.* The flash point of the oil by the open cup method should not be less than 100° C. (212° F.)

SPECIFICATIONS NO. 3.

REFINED COAL TAR PRODUCTS FOR SURFACE TREATMENT OF BITUMINOUS OR WATERBOUND MACADAM.

(Hot Application.)

1. The tar shall be free from water and shall not foam when heated to 110° C. (230° F.)

2. *Specific Gravity.* Its specific gravity at 25° C. (77° F.) shall not be less than 1.18 nor more than 1.24.

3. *Inorganic Matter.* It shall not show more than 0.5 per cent of ash upon ignition.

4. *Free Carbon.* Its free carbon content shall not be less than 12.0 nor more than 22.0 per cent. In determining the free carbon, the coal tar product will be dissolved in chemically pure cold carbon disulphide and the residue filtered on a Gooch crucible. The per cent residue minus the per cent of ash will be taken as the per cent of free carbon. No centrifuge shall be used in this test.

5. *Consistency.* The consistency of the tar as determined by the Howard and Morse float apparatus at a temperature of 32° C. (90° F.) shall not be less than 1½ nor more than 2½ minutes.

6. *Distillation.* Fractional distillation by the method described in bulletin No. 38 of the U. S. Office of Public Roads shall give results conforming to the followniq requirements, all measurements being by weight:

Up to 110° C. the distillate shall not exceed 1 per cent.
Up to 170° C. the distillate shall not exceed 8 per cent.
The total distillate up to 315° C. shall be at least 20 per cent.

DUST ON MACADAM ROADS.

On this type of construction, dust prevention is closely related to road preservation. A large portion of the dust is due to wear of the road itself, and the ability of the macadam road to form dust is therefore to some extent a measure of its wear.

It is estimated that about 50 per cent of the existing hard roads in Illinois have been constructed of crushed stone, and that the same material will be used for about 30 per cent of the hard roads

to be built during the next 5 years. While it is realized that under certain conditions there is a heavy maintenance expense connected with the use of these roads, yet their low initial cost makes them very popular. There are many sections in this State that have little or no hard surfaced roads, and as the popular desire is to secure large mileage under any hard road improvement plan, macadam or gravel roads are favored.

The methods used in the construction of macadam roads vary a great deal, and the amount of dust on the roads will depend upon the method, and also upon the quality of the stone used in their construction.

It will, therefore, be necessary to consider some phases of the construction and repair of these roads in connection with dust prevention.

A well built waterbound macadam road will be practically dustless and remain in good condition for a number of years, while a road built by simply dumping crushed limestone upon the highway, may be dusty from the start, and if not maintained properly will soon grind up and disintegrate. Even where the best methods

Figure 10. Macadam Road Built without the Use of a Roller. The Light Drag Can Be Used Effectively on This Type of Road.

of construction have been used, proper care, including dragging, patching and surfacing may be required from the beginning to obtain the best results. Most of the macadam roads in Illinois are built of rather soft limestone which will deteriorate rapidly, and it is urged that a definite plan of maintenance be put into operation as soon as practicable, and before the repair work becomes unduly expensive.

The light road drag may be used effectively in maintaining macadam roads which have been built without the use of a roller. The dragging will fill all wheel ruts and depressions, and help in maintaining the desired crown. The loose stones are brought back

into place, and on roads which have been swept by automobile traffic, much of the old bonding material can be restored to the road surface if the drag is used at the proper time.

Rut formation is of great importance in relation to both dust formation and road preservation, and steps should be taken to prevent rutting, as far as possible, and to repair all ruts and depressions before the road starts to disintegrate. Rutting may be prevented to a great extent by the construction of wide roads with a minimum crown and a hard smooth surface that is as suitable for driving in one place as in another. When ruts or depressions are formed which cannot be readily filled by the road drag, they should be filled with limestone and screenings. In this patching work, it is often necessary to make the sides of the depressions vertical by

Figure 11. Macadam Road Showing Need of Repairs by Patching.

means of a scarifier or a hand pick, and it is practically impossible to fill shallow depressions properly, if this precaution has not been taken. The depression is filled with coarse stone and thoroughly compacted into place by means of a hand tamper or a roller. The surface is then covered with limestone screenings and thoroughly soaked with water to wash fine materials into the voids of the stone and assist in bonding.

A road that is patched promptly with a suitable material will have the original surface restored, and the necessity of a surface dressing or a complete reconstruction will often be eliminated. If the macadam road has not received proper maintenance, or is subjected to heavy traffic, it may require, however, a new wearing or bonding surface. Heavy automobile traffic, especially, will soon sweep off the surface of a macadam road all bonding material and require surface treatment of some kind, either limestone screenings or bituminous material. Roads in this condition present a mosaic surface, and if they are not given proper attention the traffic

will soon loosen some of the stones and the road will ravel rapidly. A light dressing of good bonding limestone screenings as soon as indications of raveling appear, will often, however, prevent the destruction of the road. This surface dressing is applied primarily to supply bonding material and should be applied as often as required, but never to a depth greater than an inch. An excess of screening does not help in bonding, and will grind up to form dust. It is a waste of money and only a cause of dust nuisance. The screenings should be spread evenly over the road and then saturated thoroughly with water to help them in bonding to the old surface.

Figure 12. A Well Constructed Macadam Road, Four Years Old, Resurfaced with 2 Inches of Coarse Stone, Improperly Bonded. Money and Material Practically Wasted.

Under heavy automobile traffic, a surface dressing of limestone screenings is at best only temporary. Much better results may be obtained from the standpoint of dust prevention as well as road preservation, by the application of an oil or tar product. The bituminous material is applied in a manner similar to the method described in the surface treatment of bituminous roads. Care should be taken, however, that the surface has been previously swept entirely clean of dust and foreign materials, and that the stones are well exposed. Ordinary street sweepers or hand brooms may be used, but sweeping with hand brooms will prove slow and expensive. All depressions in the road are then filled with clean gravel or chips and bituminous material, and the oil or tar is applied only after the road is entirely clean and uniformly hard. The character of the road obtained and its ability to resist the wear due to traffic, will depend to a large extent upon the bond between the bituminous mat and the stone of the old road. If properly built, a surface will be obtained which can compare fav-

orably with that of a bituminous macadam, and some of the best bituminous road surfaces in this State have been obtained by this type of construction.

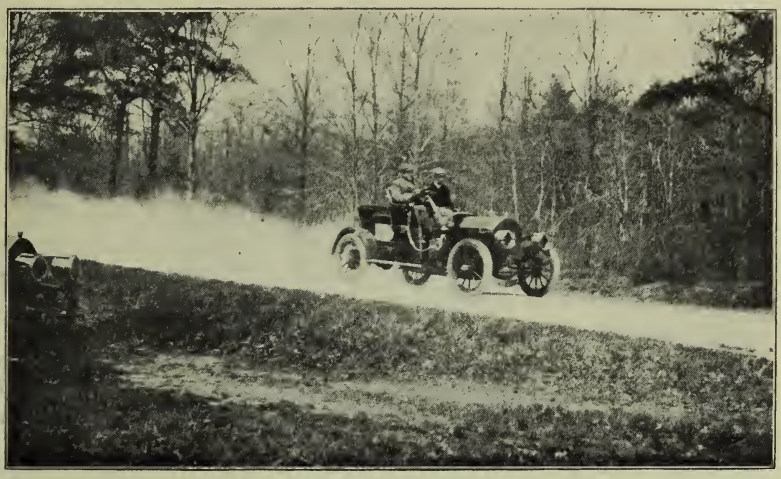

Figure 13. Showing Effect of Automobile on a Macadam Road.

As wearing qualities of a bituminous surface are largely increased by greater uniformity in the thickness of the mat, mechanical distributors are now almost exclusively employed in this work.

Figure 14. A Macadam Road Swept Free of Its Bonding Material by Heavy Automobile Traffic. An Application of Good Bituminous Material Would Be the Most Satisfactory Method of Maintaining This Road

The apparatus which is used by the Illinois Highway Department has been designed so that it will apply either light or heavy bituminous materials, and in any desired quantity. The apparatus is

composed of a steel tank of 600 gallons capacity, mounted on a heavy truck and provided with necessary attachments for heating and distribution. The steel tank is air tight and is designed to withstand an internal pressure of 100 pounds per square inch. A furnace which will burn either wood or coal is at the rear end of the distributor, while a Westinghouse air pump is attached to its front end and is connected with the steam roller so that pressure or vacuum can be secured in the tank very quickly. A guage is placed at the top of the distributor for pressure readings and a thermometer is attached at the rear end to indicate the temperature of the binder.

The bituminous material is conducted from the tank to the spray by a flexible metal hose which can be carried by one man, and permits the operator to apply either large or small quantities as desired. Attached to the end of the metal hose is a spraying nozzle as shown in figure 17.

Steam is conducted from the roller to the nozzle by a ⅜ inch pipe, and the arrangement of the apparatus is such that the bituminous material is forced through the 1½ inch hose and pipe, and as it is discharged from the nozzle, a jet of steam blows into the binder breaking it into a fine spray. In this manner, the bitu-

Figure 15. Applying Bituminous Material with Hand-pouring Cans. This Method of Application Is Slow and Expensive, But May Be Most Satisfactory for Repair Work and Small Jobs.

minous material may be applied uniformly over the surface of the road.

This apparatus has proven to be very satisfactory as it will apply any grade of binder, and in any quantity desired. The force with which the binder leaves the nozzle aids it in pentrating all interstices in the road, as well as freeing the stones of any dust coating. The practice a few years ago was to deliver the bituminous material in railroad tank cars to a convenient siding where

the material was heated and pumped directly into the distributing wagon and hauled to the road. This system may be used to advantage with fluid road oils, but with the heavier products, the expense connected with heating the railroad tank cars and the difficulty of having sufficient road surface prepared to received at one time 8,000 to 10,000 gallons of bituminous material, makes this system very impractical.

It is much more convenient to have the heavy binders delivered on the road in barrels or metal drums. These barrels or drums are emptied in auxiliary kettles having a capacity of about 450 gallons and which may be filled and heated while the pressure tank is being emptied.

The bituminous material is applied at the rate of ⅓ to ¾ gallons per square yard, either in one or two treatments, and one cubic yard of gravel or screenings is used for every 100 to 150 square yards of road surface. The price of the oils or tars used

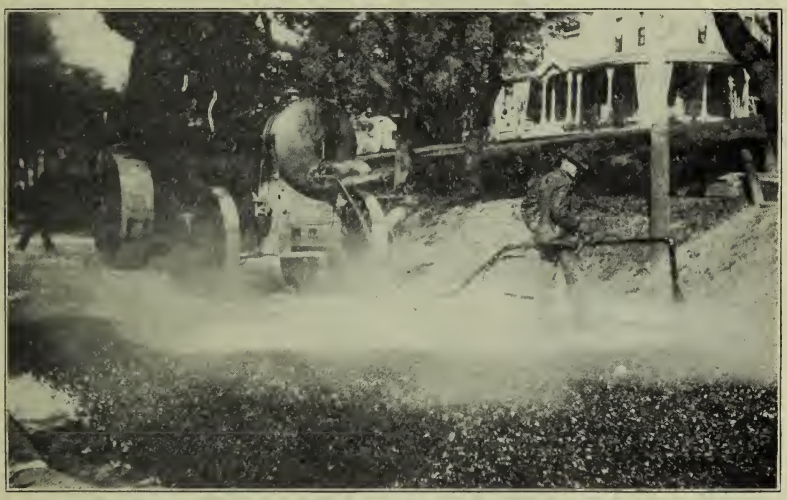

Figure 16. Applying Hot Bituminous Material by Means of Air Pressure and Steam Spray Combined.

in this surface treatment will vary from 4 to 16 cents per gallon, depending upon the grade of the material. A number of products of good quality may be obtained for about 8 cents per gallon, making the cost of construction 6 to 15 cents per square yard, depending upon local conditions. It is recommended that in choosing the grade of oil to be used, careful consideration be given to the condition of the road and to the amount of traffic upon it. In surfacing a road which has started to ravel and where most of the stone has been swept bare of all fine bonding material, a bituminous product meeting the requirements of specifications No. 1 or No. 3 should be used. An oil obtained under specifications No. 2 should be used on a macadam road when more fine material remains and the large stones are not so apparent; while a product meeting

the requirements of specifications No. 4 or 5 would give the best results on a road with a closed hard bound surface difficult to sweep clean of dust and fine material.

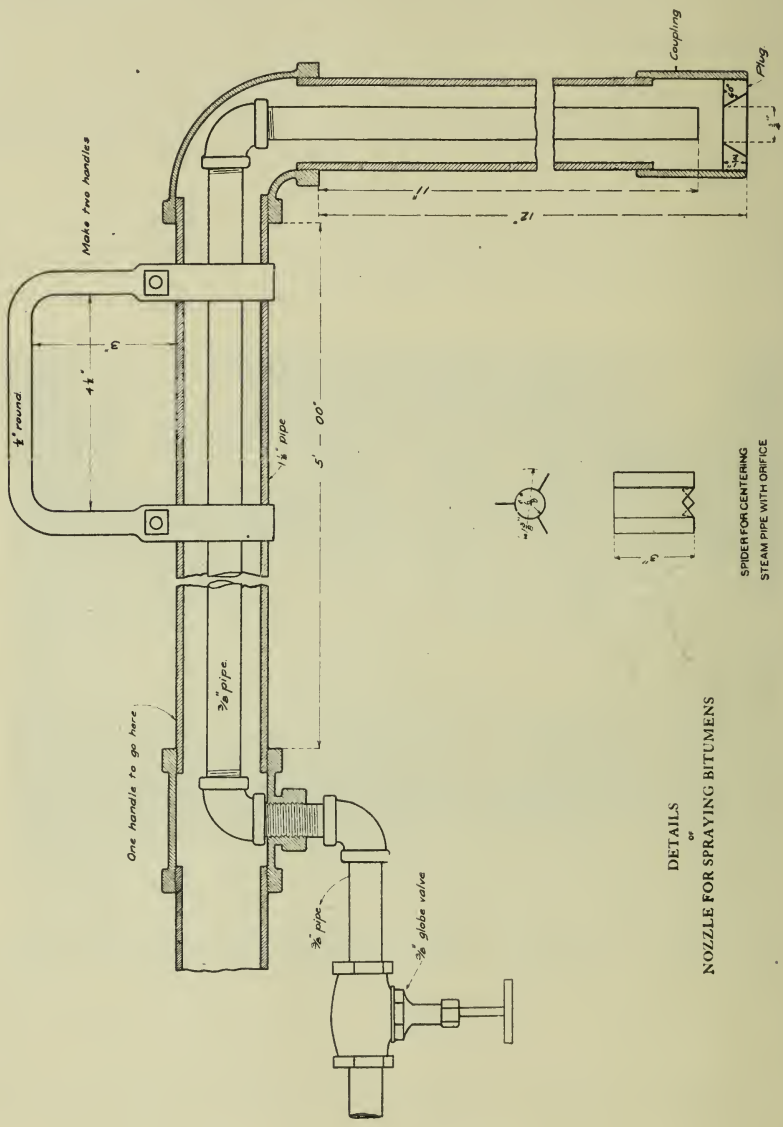

Figure 17. Details of Nozzle for Spraying Bituminous Materials. Used by the Illinois Highway Department.

The bituminous products purchased under specifications Nos. 4 or 5, may be applied cold, but a tar product meeting specifications No. 5 will tend to track under traffic, and in most cases, is not recommended.

SPECIFICATIONS NO. 4.

LIGHT OIL FOR SURFACE TREATMENT OF MACADAM OR GRAVEL ROADS.

(Cold Application.)

1. The oil shall be a fluid product, free from water.

2. *Specific Gravity.* Its specific gravity at 25° C. (77° F.) shall not be less than 0.930.

3. *Total Bitumen.* It shall be soluble in chemically pure cold carbon disulphide to the extent of at least 99.5 per cent.

4. *Naphtha Insoluble Bitumen.* Of the total bitumen, not less than 4.0 nor more than 15.0 per cent shall be insoluble in 86° B. paraffin naphtha, at air temperature.

5. *Fixed Carbon.* The fixed carbon shall not be less than 3.0 per cent.

6. *Viscosity.* When 240 cc. of the oil are heated in an Engler Viscosimeter to 50° C. (122° F.) and maintained at this temperature for 5 minutes, the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than 15 nor more than 30.

7. *Loss on Evaporation.* When 20 grams of the oil (in a tin dish 2½ inches in diameter and ¾ inch deep with vertical sides) are maintained at a temperature of 163° C. (325° F.) for 5 hours in a N. Y. Testing Laboratory oven, the loss shall not exceed 25 per cent by weight.

SPECIFICATIONS NO. 5.

TAR PRODUCT FOR SURFACE TREATMENT OF MACADAM OR GRAVEL ROADS.

(Cold Application.)

1. The tar shall be free from water.

2. *Specific Gravity.* Its specific gravity at 25° C. (77° F.) shall not be less than 1.12 nor more than 1.22.

3. *Inorganic Matter.* It shall show not more than 0.5 per cent of ash upon ignition.

4. *Free Carbon.* Its free carbon content shall not be more than 20 per cent.

5. *Viscosity.* When 240 cc. of the tar product are heated in an Engler Viscosimeter to 50° C. (122° F.) and maintained at this temperature for 5 minutes, the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than 20 nor more than 40.

6. *Distillation.* Fractional distillation by the method described in bulletin No. 38 of the U. S. Office of Public Roads shall give results conforming to the following requirements, all measurements being by weight:

Up to 110° C. the distillate shall not exceed 2 per cent.
Up to 170° C. the distillate shall not exceed 10 per cent.
The total distillate up to 315° C. shall not be less than 25 per cent nor more than 45 per cent.

When macadam roads have become so badly worn that it is impossible to keep them in good condition by ordinary methods of maintenance, a partial reconstruction of the road becomes necessary. This is often done by simply dumping a few inches of stone on the road and spreading it more or less evenly. As much more stone is required in the depressions of the old road than on the high places, the thickness of the new material will vary widely and will not compact uniformly under traffic. This will cause the road to wear unevenly again and ruts and depressions will soon be formed. By far, better results may be obtained by first loosening the surface of the old road, either by spiking or by scarifying. Some roads may then be harrowed, shaped and rolled without adding any new material. The usual method of repairing is, however, to add before rolling about 3 inches of stone, to harrow a second time and roll. Screenings are then added and the road is thoroughly soaked with water to assist in binding the surface.

Figure 18. Bituminous Macadam Road Resurfaced with Heavy Asphaltic Oil.

The cost of loosening the old road with spikes in the roller wheels is about 1½ to 2 cents per square yard, and with a scarifier from ½ to 1 cent per square yard. The average total cost of resurfacing macadam roads by the method described is about 10 cents per square yard for each inch of new material added.

In the partial reconstruction of macadam roads, it is often advantageous to build a bituminous macadam instead of a new waterbound surface. The method of construction is similar to that of the waterbound macadam just described, up to the time the stone is in place and has been rolled. Just enough clean chips are then added to fill the larger voids in the stone and a first coat of hot bituminous material is applied. Clean chips are brushed into the remaining voids of the surface, and the road smoothed with a roller. A seal coat of bituminous material is then applied and coarse sand or chips are spread again over the surface and the road

rolled lightly. If necessary, more sand or chips are added so as to prevent tracking of the surface under traffic. It is essential in this work that the stone and chips should be clean, and with dusty stone, good use should be made of the harrow to take the dust and fine material to the bottom before rolling the stone. The success of this construction depends largely upon the ability of the binder to adhere or stick to the stones. The surface should be firm, and pockets of dust or fine material should be carefully avoided. The bituminous material does not penetrate through dust and fine material, and the mat applied on a pocket of this kind is likely to pick up under traffic. It should be noted also, that as the bituminous material excludes the presence of moisture, a dust pocket will be unable to bind as it does in waterbound macadam, and will, therefore, always remain a weak spot on the road surface.

The amount of binder used will depend to some extent upon the amount of new stone added to the road. With 3 inches of new

Figure 19. Macadam Road Partly Reconstructed with Heavy Asphaltic Oil.

stone, from 1 to 1½ gallons of binder should be used for the first application and one-third to one-half gallon for the second application or seal coat. The most satisfactory binder for this type of construction is a heavy material, either tar or asphalt, such as the bituminous products used in the construction of bituminous macadam by the penetration method. Further information as to the requirements of these products may be obtained by requesting a copy of "Specifications for Bituminous Macadam Construction," from the Illinois Highway Department, Springfield, Ill.

DUST ON GRAVEL ROADS.

This type of road may be considered as a go-between or compromise between macadam and the earth road. While some gravel roads show a hard, well bound surface, others are found which are

dusty and little better than earth roads. A large variety of materials are used in their construction, due mainly to local conditions, but often also to a misunderstanding of the quality of gravels

Figure 20. A Gravel Road Needing Better Drainage and Repairs.

required. Gravels containing a large per cent of hard coarse pebbles, from three inches to one-half inch in size, and from ten to twenty per cent of red clay with good binding qualities, such as

Figure 21. A Gravel Road in Bad Condition and Which Should Be Reconstructed.

are found in the extreme southern counties of the State, will give roads which often compare favorably with waterbound macadam. These roads are somewhat dusty at first, but the excess of clay will

soon work out under traffic and leave a hard smooth surface. The maintenance of such a road is very similar to that of a crushed stone road, a good bonding gravel being used for patching and surfacing in place of stone and screening.

Figure 22. Dusty Condition of a Gravel Road After a Dry Season.

Many of the materials used consist mainly of fine sand and clay or of soft materials which grind up readily under traffic. The resulting roads are very dusty in dry weather and muddy in rainy

Figure 23. A Well Built Gravel Road, Oiled and Practically Dustless.

weather, and do not deserve the name of hard roads. The dust can be materially reduced, however, by frequent dragging and elimination of the ruts. This dragging is also of special benefit to

gravel roads built of clean gravels which lack binder and tend to keep rolling under traffic. The drag will bring any loose pebbles back into the depressions, and enough earth will usually be carried on the gravel to assist in bonding the surface. Care should be taken, however, against scraping an excess of earth to the center of the road, as this will only increase dust formation.

It is seldom that a gravel road can be constructed with a surface so hard and clean that it will permit the successful application of a heavy oil or tar. An oil which would meet specifications No. 2 might be used on a clean gravel road, while materials meeting specifications No. 4 and No. 5 would be more satisfactory for the surface treatment of the average gravel road. The lighter oils of specifications No. 6, oil emulsions, calcium chloride and miscellaneous dust palliatives can also be used on these roads for temporary dust prevention.

DUST ON EARTH ROADS.

The dust nuisance and the mud problem on earth roads in Illinois have become proverbial and need no introduction. In late winter and early spring, when the thawing out of the ground has taken place, some of these roads become impassable morasses, while

Figure 24. Proper Drainage and Occasional Dragging Would Prevent the Condition Shown in This Illustration. These Muddy Roads Are also the Ones on Which the Dust Nuisance Is the Worst after a Dry Season.

in summer from 4 to 6 inches of dust are sometimes found on these roads and a fast-moving automobile will raise so much dust that one wonders "where it all comes from."

The number of hard roads, including many gravel roads of poor quality, is relatively small, and for many years yet to come

the earth roads will represent at least 80 per cent of the roads in the State. The improvement of these roads, to make them at least passable at all seasons, is therefore of special interest. While the

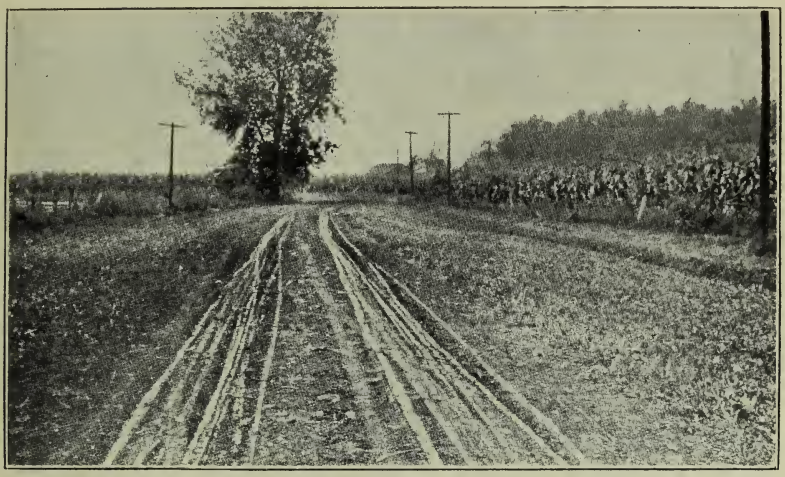

Figure 25. A Well Built Earth Road. The Center Is Maintained with the Drag.

character of an earth road cannot be changed entirely without a large expenditure, yet it may be ameliorated to a large extent at small cost.

Figure 26. This Condition of an Earth Road Was Found During September. It Shows Utter Lack of Any Intelligent Care. A Few Loads of Earth to Raise the Road Here Would Prevent Any Such Mud Hole in Summer Time, at Least.

The two most important factors in the proper maintenance of this type of road are drainage and dragging. It has been assumed during the previous discussion of the hard types of roads, that the

first step in their construction had been to secure good drainage. The earth road, however, often lacks proper drainage entirely. A few drains under the low spots and good open wide ditches will do

Figure 27. The Road Drag at Work. Note the Angle It Makes with the Road, so That a Small Amount of Material Is Pushed to the Center of the Road.

Figure 28. This Form of a Drag Suitable for Very Sticky Soils. Here the Drag Is Used Mainly as a Slicker. If It Is Turned Over, the Edge of the Plank Acts as a Cutter to Move a Small Amount of Material.

much towards preventing the formation of morasses and will tend to make the road dry rapidly. The drainage will be further assisted by the use of the road drag to smooth the surface of the road and prevent the formation of depressions.

Dragging is considered of such importance that an educational campaign on this subject was started several years ago in Illinois.

Figure 29. Effect of Slicker on Black, Gumbo Soil. Such Soil Cannot Be Dragged Successfully Until Partially Dried so as not to Roll or Stick to the Drag.

A special bulletin has been prepared by the State Highway Department on the construction of the road drag and its use, and may be obtained free of charge upon request.

OILING OF EARTH ROADS.

Of late years much attention has been given to the surface oiling of these earth roads. In the late spring of each year the State Highway Department receives a large number of requests for information upon this subject. Many grades of oils have been used under various conditions, and there seems to be a great deal of misunderstanding as to the qualities which the oil should possess, and the conditions under which it should be applied.

In general, the road oils used during the past year were too light. These light paraffin oils have practically no binding value and leave only a greasy residue. They have given trouble on many occasions, and in some cases have been a nuisance worse than the dust. A good illustration of the troubles arising from the use of a poor grade of oil is given in the following extract from a letter received by the State Highway Department during the summer of 1914 from a township commissioner of highways:

> "In oiling our streets we were unfortunate enough to place our order for oil with an old and apparently reliable house, giving us a 40 per cent asphalt guarantee, but which has proven unsatisfactory, there not being enough binder in it, and our streets have worked up a loose oily dust from one to three inches thick, covering the whole width of the streets. This is beginning to be light enough to fly in the air, and still

has enough oil in it to prevent settling by rain. It is a bad situation, but what can we do with it? I take it, it would not do to oil on it, unless a very heavy oil would cement it enough to iron out solid. We dislike to scrape it into the gutter and stop our drainage, and cannot afford to haul it off. Can you advise the best way to proceed under the circumstances?"

Light semi-asphaltic oils with a base having good binding qualities have on the contrary given good results, especially if applied under proper conditions. It has been found that even with the best grades of road oils, *it is always advisable to oil the dry road after the dust has been well settled, either by rain or sprinkling.*

Figure 30. An Oiled Earth Road.

Proper oiling of an earth road in spring will prevent the dust nuisance during the summer and will leave the road in better condition generally. The use of these oils is primarily to lay the dust temporarily, but the application of an oil of good quality will often improve the road to some extent for a long length of time. The selection of a suitable grade of oil should, however, be given a great deal more consideration than it has received in many of the small towns in Illinois in the past years. The belief that any cheap grade of oil is good enough to lay the dust is entirely erroneous. Furthermore, the application of some of these greasy paraffin oils has caused the formation in rainy weather of a slippery mud worse for traffic than the dust in dry weather.

During 1914, a number of requests to test road oils which had been bought under a "40 per cent asphaltum guarantee" were received, and it seems necessary to issue a warning against purchasing oils under guarantees of this kind which are worthless. Correspondence with township commissioners has generally brought out the information that the oils were purchased under this guarantee in the belief that the oil should leave 40 per cent of "asphalt residue," and not

realizing that the residues obtained on evaporation might be entirely different in character, nor that varying percentages of residue might be obtained, depending upon the consistency to which the oil was evaporated. It is recommended that a specification insuring products of a definite character should be used and that no road oils be bought on a guarantee of a certain per cent of "asphaltum base," or of only a certain gravity.

California was the first state to use oils extensively on earth roads. Fairly heavy oils were applied with some success, due partly to the sandy soil and fairly warm and dry climate of California. In Illinois, soil and climatic conditions make it necessary, however, to use somewhat lighter oils. An oil meeting the requirements of specifications

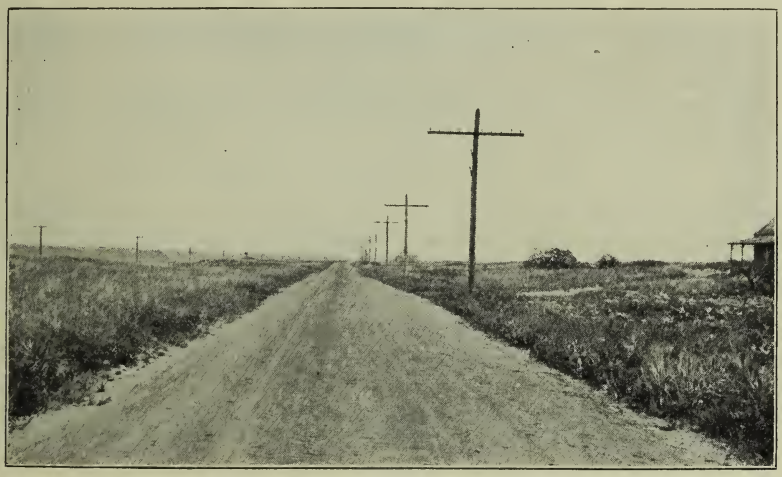

Figure 31. A Sand Oil Road Built in Layers of Sand in Which Oil Has Been Incorporated. A Similar Construction Has Been Used on a Few Earth Roads in Illinois.

No. 4 might be used successfully on a sandy soil. It is essential when using an oil of this kind that the dust should have been well settled by a good rain or repeated sprinkling, and that the road should be dry and almost dustless at the time of the application. The light oils obtained under specifications No. 6 are more suitable for clay soils and roads which are somewhat dusty at the time of application. No material, however, can be expected to give satisfaction on a road which is covered with a thick layer of dust or is badly rutted, and the less dust at the time of application, the better will be the results.

SPECIFICATIONS NO. 6.

LIGHT OILS FOR SURFACE TREATMENT OF EARTH ROADS.

(Cold Application.)

1. The oil shall be a fluid product free from water.

2. *Specific Gravity.* Its specific gravity at 25° C. (77° F.) shall not be less than 0.910.

3. *Total Bitumen.* It shall be soluble in chemically pure cold carbon disulphide to the extent of at least 99.5 per cent.

4. *Naptha Insoluble Bitumen.* Of the total bitumen not less than 1.5 shall be insoluble in 86° B. paraffin naphtha at air temperature.

5. *Fixed Carbon.* The fixed carbon shall not be less than 2.5 per cent.

6. *Viscosity.* When 240 cc. of the oil are heated in an Engler Viscosimeter to 50° C. (122° F.) and maintained at this temperature for five minutes, the first 50cc. which flow through the aperture shall show a specific viscosity of not less than five nor more than fifteen.

7. *Loss on Evaporation.* When 20 grams of the oil (in a tin dish 2½ inches in diameter and three-fourths inch deep with vertical sides) are maintained at a temperature of 163° C. (325° F.) for five hours in a N. Y. Testing Laboratory oven, the loss shall not exceed 25 per cent by weight.

Crude tars have also been employed as dust palliatives, but on account of the injury they cause to rubber tires and when tracked into houses, they are not recommended. As a rule, in surface oiling, the heaviest products that can be applied successfully under the given conditions will give the best results, and the extra cost of paying 1 or 2 cents more per gallon to obtain a suitable grade of oil, instead of the cheapest grades, will be more than offset by the differences in the results obtained.

The price of the oils used on earth roads varies from about 3 to 6 cents per gallon. They are applied at the rate of one-eighth to one-third gallon per square yard, and the average cost of application is about 1 cent per gallon. Precautions should be taken not to add an excess of oil, and in general, a couple of light applications (of say one-eighth gallon per square yard) during the year will give better results than a single application of the total amount.

MISCELLANEOUS BITUMINOUS MATERIALS.

Various oil distillates and tar products other than coal tar are at present on the market. Some mixtures of tar and asphalt have been used with good results within recent years. Water gas (oil gas) tars, although not generally considered as good road binders, have also been used with some success for the surface treatment of roads. As a rule, the oil and tar distillates have been of no importance as dust preventives and of no value as binders.

It is practically impossible, at the present time, to cover by specifications the various mixtures of tar and asphalt, which are used either as binders or dust preventives. Should it be desired to use such products, the consistency of a suitable mixture should, however, be specified; that is, a product with a float test of one and one-half to two and one-half minutes, at 32° C. might be satisfactory for a hot application on a macadam road, while a lighter product having a specific viscosity of ten to twenty-five at 50° C. would be more suitable for a dusty gravel road.

OIL AND TAR EMULSIONS.

These emulsions consist essentially of a mixture of oil and water or tar with water, and are used for laying dust. Oil and water do not mix under ordinary conditions, but a mixture may be obtained by mechanical or chemical means.

Mechanical emulsions are prepared in specially designed apparatus such as the "Emulsifix," which mixes the oil and water by means of rapidly whirling wheels. These emulsions are applied to the road as soon as they are formed, as they are very unstable and separate immediately upon standing.

Tar, vegetable and animal oils can be emulsified with water after addition of a small amount of a saponifying agent such as potash, caustic soda or ammonia. Petroleum products such as the road oils will not saponify directly with alkalies, and to obtain an emulsion, it is necessary to add a small amount of cheap soap or of saponifying materials, such as a combination of animal or vegetable fats and an alkali. Emulsions of this kind are sold in concentrated form, and are mixed with a large amount of water before being applied. Their value will vary a great deal with the character of the oil. An asphaltic or semi-asphaltic oil of good quality will tend to bind the dust particles and repeated applications will tend to form a thin mat surface, while a greasy paraffin oil may have poor dust-laying properties, and an accumulation of this oil may form in rainy weather a slippery mud very undesirable for traffic.

Many methods have been used in preparing these emulsions, and it is impossible to describe them in this bulletin. The following preparations, which have been used in the parks of Boston and Chicago, and which are described by Hubbard in "Dust Preventives and Road Binders," may be taken as illustrations of the methods and materials used. In Boston, 10 to 15 pounds of cotton seed oil soap are first dissolved in 50 gallons of water by the aid of steam heat. To every 50 gallons of soap solution, 100 gallons of semi-asphaltic oil are added and emulsified through agitation by a steam pump. This forms a stock solution containing 66 per cent of petroleum, which is further diluted with water before application.

In Lincoln Park, Chicago, a mixture of Kansas and California oils is emulsified. In this case, a naptha soap is employed because it is found to work best with the hard lake water. Fifteen pounds of the soap are dissolved in 60 gallons of hot water, and 60 gallons of Kansas oil are added. A system of hogsheads and pipes permits agitation by means of a steam pump. After a few minutes, one-half barrel of California asphaltum is added and the whole mixture is emulsified for about 20 minutes longer. The emulsion is then made up to 800 gallons with boiling water and applied with an ordinary sprinkler.

For a first application an emulsion should contain from 10 to 15 per cent of oil, while a smaller per cent may be used for repeated treatments.

Oil emulsions have been applied mainly on parkways, and to some extent on suburban roads. Up to the present time, they have not been used to any extent on rural roads, due mainly to the necessity of repeated treatments.

CALCIUM CHLORIDE.

Calcium chloride is a salt, which owes its use as a dust preventive to its hygroscopic properties and its cheapness. The fact that it is clean and odorless has contributed also, somewhat, to make it popular in many cities.

It is obtained mainly as a by-product in the manufacture of common washing soda by the Solvay process. As the use of calcium chloride for purposes other than dust-laying is relatively small, it can be obtained fairly cheap.

It absorbs moisture very readily, and in moist air will take up about twice its weight of water. It crystallizes with almost its own weight of water, but when heated to about 85° F. these crystals will melt, and at the highest temperatures on a road surface about one-third of the water which it requires for crystallization is available before it becomes solid. It tends, therefore, to retain moisture for a considerable length of time after an ordinary application of water would have evaporated.

Calcium chloride is sold either in solution or in a solid, fused or granular condition. The solid material contains about 75 per cent calcium chloride and 25 per cent moisture, and at the present time, can be purchased at $13.00 to $16.00 per ton or $2.45 to $3.00 per drum f. o. b. at points of manufacture. In solution it is usually sold in a concentrated form, containing about 40 per cent calcium chloride, and having a specific gravity of 1.40 or 41+° B. at ordinary temperature.

Calcium chloride is applied either dry or in solution. In the dry method, the granulated material is spread over the road at a rate of about 1 pound per square yard. As a rule, the calcium chloride soon absorbs enough moisture from the air to dissolve, but in hot dry weather it is necessary to follow the application by a light sprinkling with water. Solutions containing about 15 to 20 per cent of calcium chloride, or about 1½ to 2 pounds of the solid product per gallon of water, are applied at the rate of 0.3 to 0.5 gallons per square yard from ordinary sprinkling tanks. These applications must be followed from time to time by lighter treatments of about one-half these quantities, and in very dry weather with occasional sprinklings with water. The value of an application of calcium chloride, and the length of time during which it will be efficient will vary a great deal with weather conditions and with local conditions, from a few days to a few months. It is best suited for use in residence districts where the traffic is rather light and where a water supply is convenient, but should always be applied while the road is practically dustless. It is also very efficient for the temporary treatment of dust on race tracks, fair grounds, etc., but is not generally considered satisfactory for rural roads on account of the necessity of convenient water supply and repeated treatments.

Commercial calcium chloride may be obtained in an almost pure condition, and the amount of calcium chloride in a solution of such a product may be found almost directly by reading its specific gravity or degree Beaume with a hydrometer. The following table gives a

comparison of these readings, together with the calcium chloride content of the solution:

Per cent calcium chloride.....	5	10	15	20	30	40
Specific gravity at 25° C. (77° F.)....	1.04	1.08	1.13	1.18	1.28	1.40
Degrees Beaume at 25° C. (77° F.)...	6	11	17	22	32	41+

The above tables do not apply, however, when the solution contains noticeable amounts of impurities and an analysis of the solution becomes necessary. Calcium and magnesium hydrates, and sodium and magnesium chlorides are the usual impurities. Magnesium chloride has good dust-laying qualities, but the other salts have little or no value in dust prevention.

MISCELLANEOUS MATERIALS.

A number of miscellaneous materials have been used either for dust laying or for the construction of more or less dustless roads. Only two of these products, "glutrin" and "road silicate," will be considered in this chapter. Both have been used to a small extent in this State.

Glutrin is a concentrated residue of the waste sulphite liquor which is obtained as a by-product in the manufacture of wood pulp by the sulphite process. The crude liquor has little or no binding value, but when concentrated to about one-fifth of its volume to a specific gravity of about 1.25, it becomes somewhat sticky and exhibits fairly good binding qualities. It is applied diluted with its own volume of water at the rate of about one-half gallon per square yard. Its manufacturers claim that its value as a binder is due not only to its stickiness, but also to the fact that a chemical action takes place between the glutrin and the stone, resulting in a better bond of the road surface. As glutrin is, however, soluble in water, it will be washed out by frequent rain, and to prevent this, its application is often followed by surface oiling to waterproof the road.

Its cost at the present time is about 15 cents per gallon at points of manufacture, and its application seems to be limited to macadam and gravel roads.

Solutions of sodium silicate, or water glass, have been used to some extent as dust preventives and road binders. A product is now on the market under the name of "road silicate," which contains about 40 per cent of almost pure sodium silicate. Its specific gravity is approximately 1.40, and it is sold at about $15 per ton. When applied to a macadam or gravel road, it will tend to bind the stone either by leaving a film of water glass between the stone, or with basic stone such as limestone, by forming some insoluble silicates. As ordinarily applied, however, in rather weak solutions, it is not present in sufficient quantities to form a strong bond, and the thin cementing films which are formed are likely to break under traffic. On account of its high cost it is doubtful, however, if enough sodium silicate can be added to give a satisfactory road without making the cost of construction prohibitive.

SUITABILITY OF MATERIALS.

It has been seen from the foregoing discussion that the success in the building of dustless roads will depend mainly upon two factors:

1. Proper construction when conditions of weather and (in surface treatment) conditions of the road are suitable.

2. Suitable materials.

Proper construction is to a large extent a question of experience. It is recommended, however, that in all surface treatments with oils and miscellaneous dust preventives, all materials be applied when the road is in a practically dustless condition after all ruts and depressions have been eliminated, and that the road (also the stone and sand) be dry when bituminous materials are applied.

Suitable materials are here understood to mean, not only good materials, but the materials which are best suited for the individual conditions of each road. Enough emphasis cannot be placed upon the fact that even a very good product may not be desirable for a certain work. Many factors are to be taken into consideration in the selection of a bituminous material or other dust preventives, and chief among them, the type of road, the condition of the surface, the character of traffic, the requirements of the public and the amount of money available. After a product has been decided upon, it should be purchased under a well written set of specifications which will eliminate all undesirable materials. An attempt has been made in this bulletin to give a number of specifications for bituminous products in connection with various types and conditions of road surfaces. It should be remembered, however, that the specifications are given merely as a guide, and that, while the materials which meet their requirements will be suitable in most cases, yet peculiar conditions may arise for which they are not satisfactory. Good judgment in the selection of materials requires a great deal of experience as to their qualities and character. As few of the township and city officials are usually in position to acquire this experience, the State Highway Department stands ready to assist them in securing the desired information. Its testing department is equipped to make the tests of all road materials, and it will furnish advice to road officials free of charge. It is urged, however, that all available information in regard to conditions of road and traffic be given when requests for testing of materials are made. This information will save time and will often contribute a great deal towards the success of the construction.